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CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that annexed is a true copy of the Provisional Specification as filed on 1 December 2003 with an application for Letters Patent number 529891 made by PROPELLER JET LIMITED.

Dated 2 August 2004.

PRIORITY DOCUMENT
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Neville Harris

Neville Harris
Commissioner of Patents, Trade Marks and Designs

COMMISSIONER OF PATENTS, TRADEMARKS & DESIGNS
NEW ZEALAND

330 High Street, Lower Hutt and 17 Toop Street, Seaview
PO Box 30687, Lower Hutt, New Zealand or DX SX 11129, Wellington
Phone: +64 4 560 1600, Fax: +64 4 560 1691, www.iponz.govt.nz

529891

Patents Form No. 4

PATENTS ACT 1953

PROVISIONAL SPECIFICATION

IMPELLER DRIVE FOR A JET PROPULSION UNIT

We, Propeller Jet Limited, a New Zealand company of C/- Domeburn Station, RD 7, Gore, Southland, New Zealand, do hereby declare this invention to be described in the following statement:

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TITLE Impeller drive for a jet propulsion unit

FIELD OF THE INVENTION

This invention generally relates to water jet propulsion apparatus for propelling boats and other watercraft. The apparatus it is also applicable to stationary pumps and electric generating plants.

BACKGROUND OF THE INVENTION

Water jet propulsion apparatus operate by utilizing the reaction forces resulting from propelling a mass in one direction thus creating an equal and opposite force in the other direction.

A high-pressure jet produces its thrust substantially in the nozzle section at the rear of the device. The impellers that produce the thrust are fine in pitch so that they are able to develop a pressure head, which in turn creates a large change in velocity as the water is forced through a rapidly reducing outlet. The water speed forward of the nozzle section in a water jet operating above the water line, is not the same as the water speed of the boat or craft. The water speed in the intake and impeller section is below boat speed, and so the change in velocity is calculated from the net change in velocity from the intake to the outlet of the nozzle, the greater change taking place in the latter.

Another form of water jet propulsion apparatus consists in a unit which delivers a considerable mass of water through an outlet nozzle but at a comparatively low pressure. Such devices are commonly known as a low pressure, high mass unit.

Water jet propulsion systems have attributes specific to the characteristic relating to the design of the unit. It is known that high pressure jet propulsion systems are particularly effective in shallow water operation. The shortcomings of a high pressure jet propulsion system however, relate generally to its slow to mid speed operation. A water jet requires high pressure in order to create a velocity change in the nozzle section sufficient to produce usable thrust. To achieve this, the known systems employ a fine pitched, pressure-inducing impeller or impellers, often followed by one or more stator sections, and then a reducing nozzle. The fine pitched impellers range

from about 11-20 degrees, and thus have a reduced advance coefficient (ratio of boat speed to impeller tip speed). At slow impeller revolutions, they develop relatively low thrust.

A water jet propulsion system has a markedly reduced water speed forward of the upstream impeller. Water diffuses into an intake section in front of the upstream impeller, and as it does so, it slows down. This slowing down of the water as it passes through the body of the pump reduces losses through friction. The stators (water straightening vanes, placed downstream from the impellers) also represent a potential for frictional losses if the water speed through them is raised too high. The use of low advance coefficient impellers keeps the velocity low, but enables very high pressure to be produced in the nozzle section. This locks a high-pressure jet system into having a configuration where a relatively low mass of water is accelerated to very high velocities in a nozzle section located downstream from all of these structures.

For a user who requires both good boat speed, but also slow speed control at low engine revolutions, the high pressure jet has limitations, as it expels a relatively low mass of water at low plume velocity. Where low impeller speeds and high propulsor thrusts are required, the high-speed jet is not a good substitute for a propeller system.

Considerable development has therefore been directed towards improving the efficiency of water jet propulsion units and in particular to provide a propulsion unit that can act as an effective high pressure low mass device and a low pressure high mass device.

PRIOR ART

A high pressure jet propulsion system is disclosed in U.S. Patent 3044260 (Hamilton). The Hamilton system is characterised by impellers that have a low advance coefficient. A greatly reducing nozzle cross-sectional area results in a very large change in water velocity, and thus thrust is produced.

Other forms of high pressure pumps have been described in U.S. Patent 3,269,111 (Brill) and 3,561,392 (Baez).

A variety of adjustable discharge nozzles have been described for instance in US Patent 5,658,176, (Jordan) which teaches a nozzle pressure control device

designed to optimise the pressure in a high-pressure pump. Jordan does not define the conditions necessary for optimal efficiency in a low-pressure pump, it refers to the "pumping means forcibly delivers the water through the nozzle thereby propelling the craft..."(Column 1 lines 14-17). This is clearly referring to the thrust being generated in the nozzle section. The inclusion of a stator section also precludes this device from being a low-pressure pump.

U.S. Patent 6,293,836 (Blanchard) describes an adjustable nozzle for a high-pressure pump. At column 1 lines 27-29 there is a reference to pressure being developed in the nozzle, where it is stated: "A smaller opening is also desirable for low-speed manoeuvering, as it would result in higher velocity of the exiting water flow at low engine rpm."

There has been a previous attempt to overcome the limitations of high pressure water jets. US Patents 5,634,832 (Davies) and 6,193,569 (Davies) describe an above the water line jet operating at low pressures. Unlike traditional pressure jets, where the thrust is developed in the nozzle section, a low-pressure jet produces a change in velocity predominantly across its impeller blades. By utilising the very low intake water velocities forward of the impellers, large gains in efficiency can be achieved. In order to be at its most efficient, the pump backpressures must be kept as low as possible, to allow the accelerated water minimal impedance as it leaves the downstream impeller. Such a low pressure device therefore does not use a constricted outlet for the nozzle which is in contradistinction to the manner in which the nozzle section of a high pressure jet operates.

The counter rotating impellers also provide straight or linear flow at the outlet, thus removing the need for stators. This also means that once the water has been accelerated to its terminal velocity, there should be no structures present that will slow the velocity of the water.

The impellers for a low pressure jet ideally should be designed to have a relatively high advance coefficient and this requires course-pitched impellers. Likewise, the body of the pump should not create drag or friction as a result of it being exposed to the fast moving water under the boat.

US Patent 5,846,103 (Varney et al) describes a pump jet that is suspended

under the boat, so that the intake is subject to boat speed water velocities.

The above prior art and known technology in this field teach that in order for a low pressure/high mass jet to operate efficiently, a vital parameter must be taken into account as impeller revolutions increase, and the change in velocity across the blades of the impellers goes up.

In a low pressure, high mass pump, air being drawn back into the pump by the drop in pressures developed over the impellers and in the intake, induces ventilation, similar to a propeller operating near the surface of the water. Previously, the Davies et al. low pressure pumps have been defined as requiring an outlet cross-sectional area ratio of about 0.55 to less than the swept area of the front impeller. What this is saying, is that the outlet area starts at about half the area of the front impeller, and operates with nozzle size that is equal to, and larger than that.

The ratio of the exhaust outlet is linked directly to the change in velocity across the impellers, and starts with a very large exhaust outlet which is about half the front impeller diameter (0.55) at very low impeller rotational speeds, when the craft is on the plane, and gets progressively smaller as the rotational energy from the impellers is imparted to the water, and a greater change in velocity starts to take place.

Operating the pump with exhaust outlet sizes much less than the area suggested by a ratio of 0.55, particularly at high rotational velocities, does not result in a drop in efficiency. At higher rotational speeds it is imperative to reduce the exhaust outlet area in order to prevent ventilation from reducing the normal operation of the pump. This smaller opening at the outlet is not changing the pump into a high-pressure pump; it is simply altering the outlet to accommodate the change in velocity that takes place as the water accelerates over the impellers, so that ventilation will not occur.

At each range of impeller tip speeds there is an optimum exhaust outlet size that creates a balance between two opposing variables, that is ventilation, and too much backpressure. An adjusting anti-ventilation device can be placed in the exhaust outlet to accommodate the different priming requirements across a wide range of impeller revolutions per minute. This device is not always necessary, as the exhaust outlet size may be fixed at a target setting, however there are some situations where the use of such a device will aid the operation of the jet. At slow internal pump

velocities, the exhaust outlet opening would be at its largest, and would be characterised by a very low plume velocity. If the outlet was to remain under the water during operation, then the outlet can be larger again. As the water velocity increases through the pump, the exhaust outlet must reduce in area, to control ventilation, and enable the craft to be driven onto the plane, and up to very high speeds.

OBJECT OF THE INVENTION

It is an object of this invention to provide an improved low pressure high mass pump which will be efficient at various boat speeds and in particular which at higher boat speeds will provide the desired efficiency.

SUMMARY OF THE INVENTION

In one form the jet propulsion unit comprises an intake housing, a pump housing, and an outlet housing,

a pair of counter-rotating spaced apart impellers located between the intake housing and the outlet housing, said impellers being constructed with opposite pitches and being mounted on shafts within the pump housing,

wherein water which enters the intake housing passes to the upstream impeller which imparts both radial and axial energy to the water which is then passed to the downstream impeller which is arranged to remove a substantial amount of the radial energy in the water is it passes the blades of the downstream impeller,

the construction and arrangement being that one of the impellers is arranged to impart less energy to the water than the other impeller.

Preferably the upstream impeller imparts greater energy to the water than the downstream impeller.

Preferably the rotational speed of the downstream impeller is less than the rotational speed of the upstream impeller.

Preferably the impellers are mounted on concentric counter-rotating shafts.

Preferably the impellers are driven from a single engine through reduction gearing to provide the desired ratio of rotational speeds between the upstream and

downstream impellers.

Preferably the ratio of rotational speeds between the downstream and the upstream impellers is fixed.

Preferably the ratio of rotational speeds between the downstream and the upstream impellers can be altered.

Preferably each impeller is driven by a separate engine.

Preferably the intake housing is bulged outwardly upstream of the upstream impeller.

Preferably a wear ring is positioned on the interior of the wall of the housing to register with the tips of the blades of the impellers.

Preferably means are provided to vary the cross sectional diameter of the outlet.

Preferably the cross sectional area of the outlet can be varied to an optimum size to allow the maximum amount of water to exit the unit while also controlling ventilation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG 1 is a side elevation sectional view of one form of a low pressure/ high mass water jet pump according to this invention in which the upstream impeller is smaller than the downstream impeller. The Figure also includes an illustration of a fixed form of ventilation device.

FIG 2 is a side elevation sectional view of another form of the invention in which both impellers are of full diameter and including an adjustable ventilation device.

Figure 3 is a side elevation sectional view of another form of the invention illustration the positioning of the ventilation control device between the two impellers.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Prior to the present invention, the construction of either a high pressure low mass unit, or a low pressure high mass unit comprised the utilization of two (or more) impellers mounted on concentric shafts and rotated in opposite directions. Both impellers were of essentially the same constructions apart from the necessity for the blades of one impeller to be of an opposite pitch to the blades of the other impeller. Both impellers in the prior art units were arranged to impart a similar amount of energy to the water, typically by driving both impellers at the same revolutions per minute.

The theory of twin impellers is that the upstream impeller will impart both a radial and an axial energy to the water which is delivered to the downstream impeller. Because the downstream impeller is rotating in the opposite direction, while additional axial energy is imparted to the water, the radial energy in the water passing the blades of the downstream impeller is also largely converted to axial energy.

It has been found that if both impellers are of the same or similar construction, but with opposite pitches and rotate at equal speeds, this can create unwanted drag on the water with inadequate results. To enable efficient operation it is necessary to balance the amount of work being done by each impeller.

In New Zealand patent application 626666, the contents of which are herein imported by reference, a modification to known twin impeller jet propulsion units is disclosed where the upstream impeller is formed to have less efficiency than the downstream impeller. Preferably this is obtained by forming the blades of the upstream impeller to have a lesser diameter than the downstream impeller. In addition a clearance was left between the outer tips of the upstream impeller and the interior wall of the pump housing with the object of rendering the upstream impeller less efficient than the downstream impeller. The main purpose of the upstream impeller was to induce a swirl into the water as it passes the impeller and to minimise drag associated with the upstream impeller. These modifications, and in particular the reduced diameter and the changes to the aerofoil shape of the blades of the upstream impeller, reduced the efficiency of the upstream impeller allowing more water to pass without unduly creating drag. It is considered that without these modifications, the upstream impeller acts as a form of a dam with deleterious results on the performance of the unit.

In accordance with the present invention it is proposed to balance the work done by the two impellers and to that effect the delivery rate of the upstream impeller must be increased, or conversely the ability of the upstream impeller to hold back pressure must be reduced so the downstream impeller can 'suck' more water.

It has also been surprisingly found that by varying the relative speed or rotation of the two impellers a considerable increase in the efficiency of the unit can be secured. In particular it was found that when the rotational speed of the upstream impeller was increased and the rotational speed of the downstream impeller remained the same, the efficiency of the unit increased while still maintaining linear flow at the outlet. Consequently the characteristics of the unit can be considerably changed by adjusting the rotational speed of the two impellers, particularly so that the rotational speed of the downstream impeller is less than the rotational speed of the upstream impeller. This observed effect occurs whether or not the two impellers are of similar construction.

As a result of the present invention, it has been surprisingly found that provided the rotational speed of the downstream impeller is less than the rotational speed of the upstream impeller, considerable efficiencies can be obtained. In one form of the invention each impeller can be separately driven, such as by an independent engine so that the relative speeds of the two impellers can be readily adjusted to provide the maximum efficiency. For instance it has been found that at higher boat speeds, very little rotational speed needs to be imparted to the downstream impeller, while at lower boat speeds, it can be advantageous to impart more rotational speed to the downstream impeller. The relative speeds of the two impellers can also be fixed such as when both impellers are driven by the same engine and in such a case the difference in the rotational speeds can be obtained by suitable gearing. Such gearing can be of a fixed ratio or can be made variable by methods as are known in the art.

The significant advantages provided by the present invention lie in the fact that because the unit operates essentially as a low pressure high mass unit, water issuing from the outlet of the jet unit will be traveling at a speed which is not much greater than boat speed. This will significantly reduced the risk of erosion resulting from the high speed plume of water generated by high pressure low mass devices. In addition, because water issues from the outlet at a comparatively low pressure, low speed maneuverability of the unit is enhanced. Further because one impeller is not working

against the other (they are in balance) greater thrust and fuel savings are achieved.

Fig 1 depicts one form of a low pressure/high water mass water jet pump that has an intake housing 1, a pump housing 13, and an outlet housing 23. As illustrated in the drawing the intake 1 is bulged at 1a just forward of the upstream impeller 2a which will tend to reduce the velocity of the water in the intake and add volume.

In the form of the invention illustrated in Figure 1, a pair of counter-rotating impellers 2a and 2b constructed with opposite pitches are supported on counter rotating concentric shafts 3 and 3a which enter the intake housing 1 through an extension 4 formed as part of the intake housing. The shafts are supported by bearings 5 within a shaft support 25 and are protected from water damage by seals 17. As particularly illustrated in this Figure, the diameter of the upstream impeller 2a is less than the diameter of the downstream impeller 2b and a gap 2c is left between the tips of the blades of the impeller and the inner wall of the housing 13. This aspect was disclosed in our New Zealand Patent Application 626666 and the purpose of the smaller diameter upstream impeller 2a was to make the upstream impeller less efficient than the downstream impeller 2b. The modification of the present invention is that if the upstream impeller is made to do more work than the downstream impeller, such as by reducing the revolutions of the downstream impeller, then surprising efficiency gains are possible.

The driving means and the method for creating counter-rotation on the shafts is not shown because such means is well known in the art. Various engine combinations, gearings and gearboxes can be used to give the desired opposite rotation on the shafts. The counter-rotation of the impellers may also be achieved by driving the impellers through a gearbox placed behind the downstream impeller, between the two impellers, in the intake section, or any combination between these positions.

In one form of the invention, each impeller is driven through appropriate gearing by a separate engine (not shown in the drawings). In another form, both impellers are driven through appropriate gearing by the same engine.

In a highly preferred form, the gearing is arranged so that the relative speeds of the two impellers are fixed in a manner that the downstream impeller will always rotate at a different speed than the upstream impeller.

In another form of the invention, the gearing is arranged to be variable so that the rotational speed of the downstream impeller relative to the rotational speed of the upstream impeller can be adjusted, either while the unit is in operation, or when the unit has been stopped. Suitable forms of adjustable gearing to achieve this requirement are known in the art and form no part of the present invention.

It will also be understood that while in a highly preferred form, the impellers are mounted on concentric, counter rotating shafts, in a modification the shafts can be separate with appropriate changes to the construction to enable the two impellers to be axially aligned.

The impellers 2a and 2b are locked onto the driven shafts by keys 21, and held in place by locking nuts 20. The inner shaft is supported at the rear of the unit inside the outlet housing 23 by a coned structure 18 which is held in place by thin hydrodynamic vanes 15. These vanes should be little in number and streamlined, so that they do not unnecessarily induce drag or friction in the pump housing section 13 which in this embodiment is depicted as tubular, and parallel.

The pressure of water in the intake will be lower than the pressure between the impellers 2a and 2b and as the speed of the boat increases, this will increase the pressure of water in the intake and consequently the pressure between the impellers will progressively increase with the speed of the boat until the boat reaches an optimum speed where the pressure will not longer increase.

Once rotational energy is applied to the shafts and the impellers start to turn, they produce a drop in pressure in the intake housing, which primes with water. The arrow 9 depicts the direction of water flow.

Preferably a wear ring or the like (not shown in the drawings) is located inside the pump housing around the tips of the blades of the upstream and the downstream impeller.

The counter-rotation of the downstream impeller 2b removes the rotational energy imparted to the water by the upstream impeller 2a, resulting in linear flow in the exhaust outlet 23. This removes the need for straightening vanes (stators) commonly found in other jet propulsion units.

As the water in the intake passes through the upstream impeller, it is spun and driven outwards towards the inner walls of the pump housing. As the water progresses to the rear of the upstream impeller 2a it will be annulus in appearance and spiraling rearwards along the pump housing walls towards the downstream impeller. The downstream impeller will tend to straighten the water by removing the radial energy and at the time the water exits the rear of the downstream impeller 8, it is essentially axial in flow, and annulus in shape.

As illustrated in this embodiment, the pump may also include a ventilation device. In one preferred form an outlet 23 of constant internal dimensions may be employed and a smooth coned plug 18 is located in the outlet. The diameter of the plug increases towards to the outlet 23. The desired cross-sectional area of the outlet 6 will vary according to the rotational velocities of the water over the impellers, and will preferably fall between about 0.55 and 0 as a ratio of the area of the upstream impeller blades and the outlet. If necessary, the diameter of the cone 22 can be adjusted to give maximum thrust at the desired outlet water velocity. The cross sectional area 6 of the outlet 23 formed by the combination of the interior wall of the outlet 23 and the plug 18 is such that it will prevent or substantially prevent air from re-entering the pump and thus cause ventilation. In addition the cross sectional area 6 of the outlet 23 will be such that back pressure will be maintained against the downstream impeller as low as possible while presenting minimal impedance to the water as it exits the outlet.

As illustrated in Figure 2 where like parts have the same reference numerals, the upstream impeller 2a is the same diameter and construction, but of opposite pitch, as the downstream impeller 2b. However in this embodiment the portion 16 of the housing has a reducing diameter towards the outlet and the pump includes an adjustable ventilating device in the form of a coned structure 18 which is slidably located on the rear of the inner shaft support structure 10. This arrangement will allow the cross sectional area 6 of the outlet 23 to be varied and therefore the ventilation and back pressures will be controlled automatically using the flow of water over the coned structure. The structure includes a tension spring 12 positioned between a back stop 19 and the rear face of the portion 11 of the coned structure 18 which will normally position the coned structure in the forward position. As the pressure of water flowing over the coned structure rises, this will tend to move the coned structure towards the outlet by further compressing the spring 12. The rearward movement of the coned structure will thereby alter the outlet cross sectional area 6 to accommodate

different water velocities produced by the pump and maintain an outlet ratio necessary to prevent or at least minimise ventilation across a range of water velocities.

As illustrated particularly in Figure 3, the ventilation control device is located between the upstream impeller 2a and the downstream impeller 2b. In this embodiment, the diameter of the interior of the housing is altered adjacent the ventilation control device by means of an adjustable skirt 26 that encircles the interior of the pump housing in between the two impellers 2a and 2b. The skirt 26 is preferably formed so it can retract into the pump housing and is adjustable. In this embodiment, the downstream edges of the impeller blades of the upstream impeller 2a are extended at 25 and are contiguous to the boss 24. By this arrangement, the skirt 26 which may be fixed or adjustable can act against the extension 25 of the impeller blades to prevent or minimise ventilation. The combination of the skirt 26 and the extensions 25 of the impeller blades provides a passage 7 of reducing diameter to provide the desired variation in outlet ratio necessary to prevent ventilation. The advantage of this configuration is that it is not necessary to use the outlet plug as illustrated in the versions of Figures 1 and 2. The ventilation control device can be fixed in the appropriate location, or it can be spring loaded in a manner similar to that illustrated in Figure 2.

Methods for keeping particles or marine growth away from the moving parts may also be employed. These may include flexible covers, or sealed compartments as will be known in the art.

It is understood that those skilled in the art could make various changes within the structures present inside the pump to carry out a similar function. The particular representation of the invention as presented in the drawings is not intended to be restrictive, or limiting, and it is the intention that the invention will include all configurations falling within the concept of the invention.

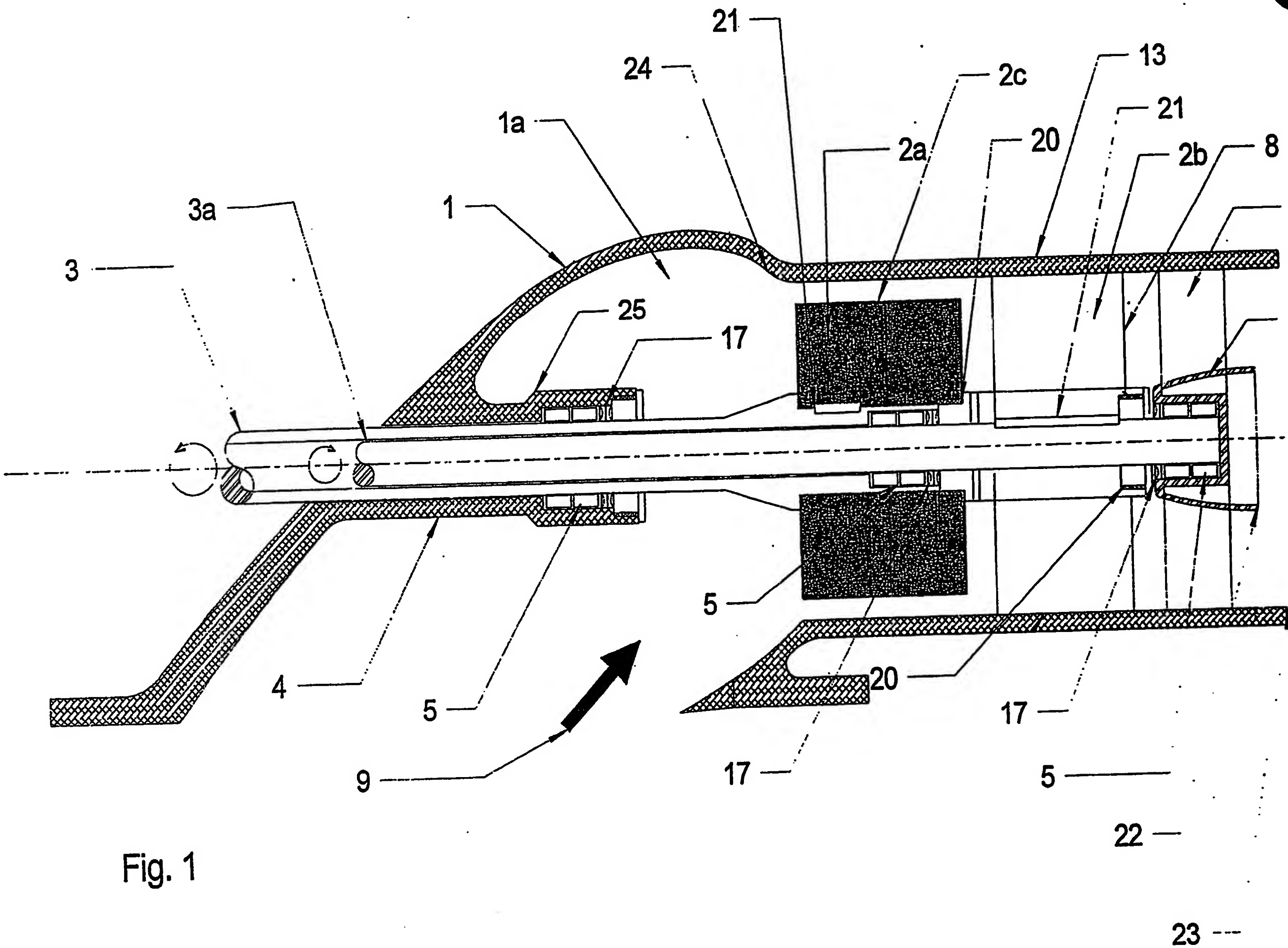

Fig. 1

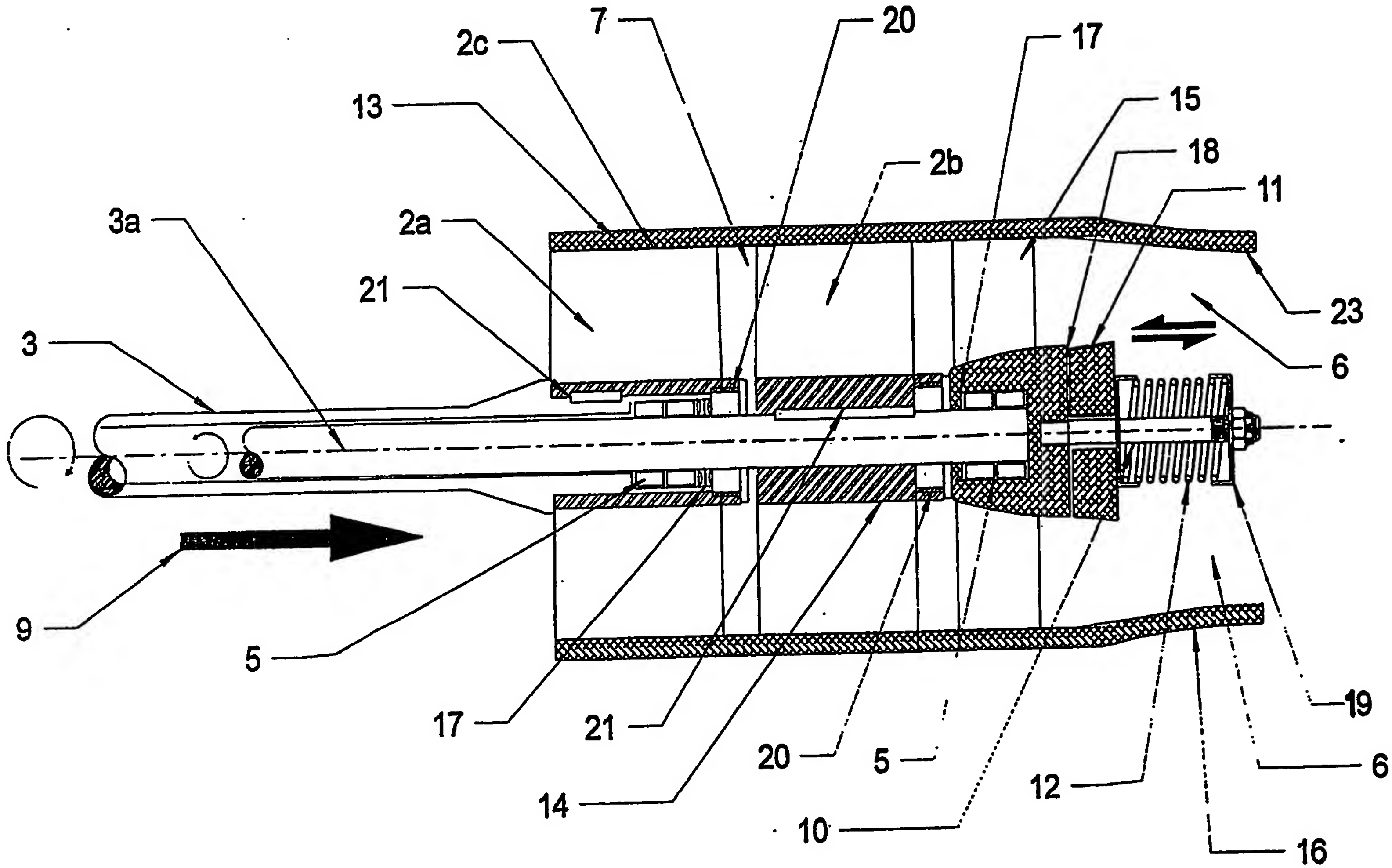

Fig. 2

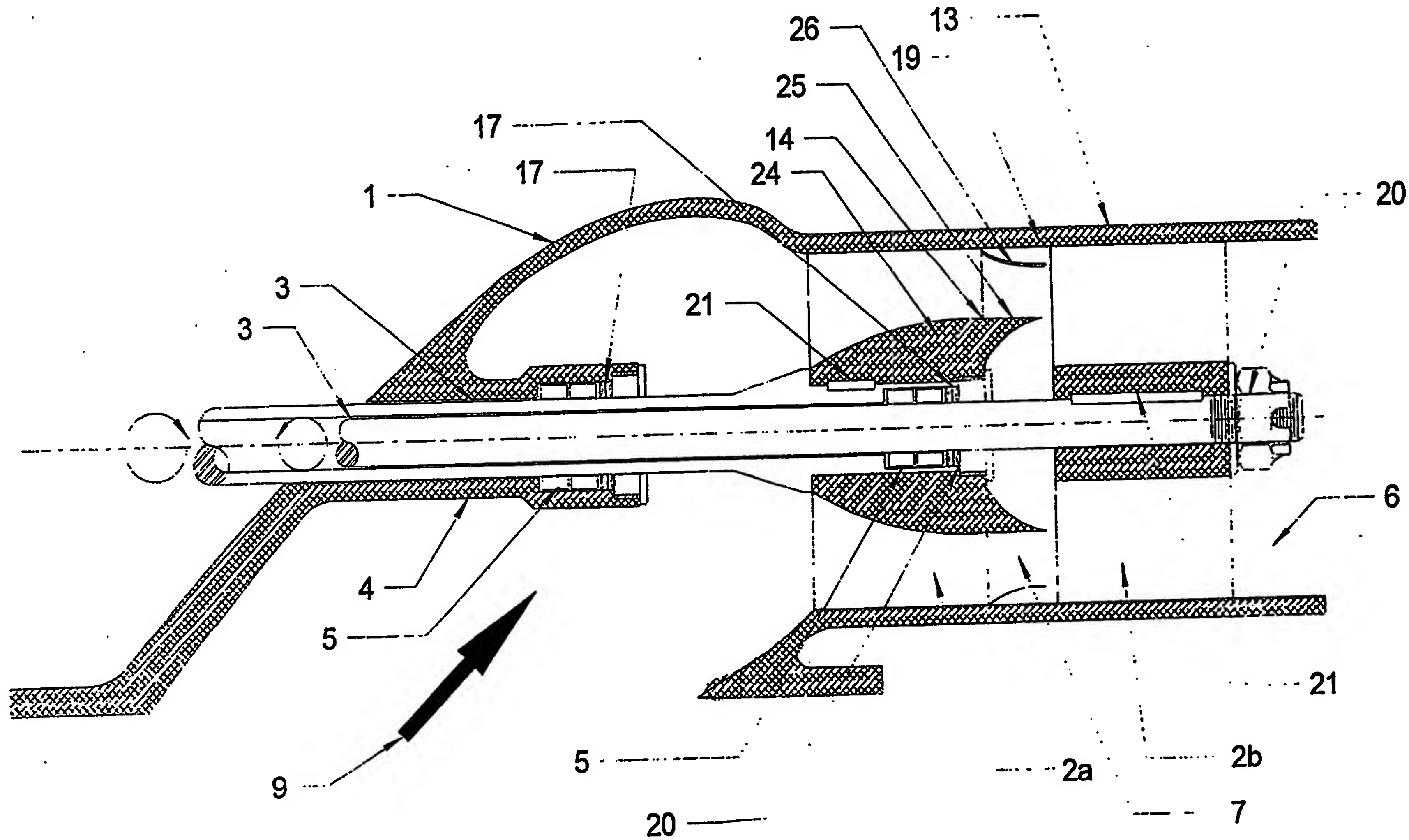

Fig. 3